

What is claimed is:

1. An ignition apparatus having a spark plug comprising:  
a mounting bracket (10) capable of being mounted to an  
5 internal combustion engine;

a center electrode (30) insulatedly-supported by the  
mounting bracket, one end (31) of which being a cylindrical form  
and exposedly extending from one end (11) of the mounting  
bracket; and

10 an earth electrode (40) having one end coupled with the  
one end of the mounting bracket and the other end on which one  
surface (43) is formed to face to the one end of the center  
electrode, the one surface having a cylindrical protrusion (41)  
being secured thereon and extending toward the center electrode  
15 so as to face the one end of the center electrode, a spacing  
formed between the one end of the center electrode and the  
protrusion of the earth electrode serving as a discharge gap  
(50), both of the one end of the center electrode and the  
protrusion of the earth electrode being 2.3 [mm] or less, and  
20 an amount of ignition energy required by the spark plug being  
less than 17 [mJ].

2. An ignition apparatus having a spark plug comprising:  
a mounting bracket (10) capable of being mounted to an  
25 internal combustion engine;

a center electrode (30) insulatedly-supported by the  
mounting bracket, one end (31) of which being a cylindrical form  
and exposedly extending from one end (11) of the mounting  
bracket; and

30 an earth electrode (40) having one end coupled with the  
one end of the mounting bracket and the other end on which one  
surface (43) is formed to face to the one end of the center  
electrode, the one surface having a cylindrical protrusion (41)  
being secured thereon and extending toward the center electrode  
35 so as to face the one end of the center electrode, a spacing  
formed between the one end of the center electrode and the

protrusion of the earth electrode serving as a discharge gap (50), both of the one end of the center electrode and the protrusion of the earth electrode being 2.3 [mm] or less, and a density of ignition energy required by the spark plug being less than 32 [W].

3. A spark plug comprising:

a mounting bracket (10) capable of being mounted to an internal combustion engine;

a center electrode (30) insulatedly-supported by the mounting bracket, one end (31) of which being a cylindrical form and exposedly extending from one end (11) of the mounting bracket; and

an earth electrode (40) having one end coupled with the one end of the mounting bracket and the other end on which one surface (43) is formed to face to the one end of the center electrode, the one surface having a cylindrical protrusion (41) being secured thereon and extending toward the center electrode so as to face the one end of the center electrode, a spacing formed between the one end of the center electrode and the protrusion of the earth electrode serving as a discharge gap (50), both of the one end of the center electrode and the protrusion of the earth electrode being 2.3 [mm] or less, and the discharge gap being 0.7 [mm] or less in length.

4. The spark plug of claim 3, wherein the mounting bracket (10) has an outer circumferential surface therearound on which a threaded part (12) is thread-coupled with the internal combustion engine, a thread diameter of the threaded part being M12 or less.

5. A spark plug comprising:

a mounting bracket (10) capable of being mounted to an internal combustion engine;

a center electrode (30) insulatedly-supported by the mounting bracket, one end (31) of which being a cylindrical form

and exposedly extending from one end (11) of the mounting bracket; and

an earth electrode (40) having one end coupled with the one end of the mounting bracket and the other end on which one surface (43) is formed to face to the one end of the center electrode, the one surface having a cylindrical protrusion (41) being secured thereon and extending toward the center electrode so as to face the one end of the center electrode, a spacing formed between the one end of the center electrode and the protrusion of the earth electrode serving as a discharge gap (50), both of the one end of the center electrode and the protrusion of the earth electrode being 2.3 [mm] or less, and a protruding length (L) of the protrusion being 0.3 [mm] or more.

6. The spark plug of claim 5, wherein the protruding length (L) is 1.5 [mm] or less.

7. The spark plug of claim 3, wherein both of the one end (31) of the center electrode (30) and the protrusion (41) of the earth electrode (40) are 1.1 [mm] or less in diameter.

8. An ignition apparatus comprising:  
the spark plug (S1) of claim 3; and  
an ignition power supply (60) for applying voltage to the center electrode (30) and the earth electrode (41).

9. An ignition apparatus comprising:  
the ignition plug (S1) of claim 3; and  
an ignition power supply (60) having an ignition coil for applying voltage to the center electrode (30) and the earth electrode (41), the ignition coil being 22 [mm] or less in coil diameter.

10. An ignition apparatus comprising:  
a spark plug having  
a mounting bracket (10) capable of being mounted to an

internal combustion engine,

a center electrode (30) insulatedly-supported by the mounting bracket, one end (31) of which being a cylindrical form and exposedly extending from one end (11) of the mounting bracket, and

an earth electrode (40) having one end coupled with the one end of the mounting bracket and the other end on which one surface (43) is formed to face to the one end of the center electrode, the one surface having a cylindrical protrusion (41) being secured thereon and extending toward the center electrode so as to face the one end of the center electrode, a spacing formed between the one end of the center electrode and the protrusion of the earth electrode serving as a discharge gap (50), both of the one end of the center electrode and the protrusion of the earth electrode being 2.3 [mm] or less, and the protrusion being made of one selected from a group consisting of a platinum-based alloy and an iridium-based alloy; and

an ignition power supply (60) for applying voltage to the center electrode (30) and the earth electrode (41), a positive voltage being applied to the center electrode by the ignition power supply when a discharge starts.

11. The ignition apparatus of claim 1, wherein both of the one end (31) of the center electrode (30) and the protrusion (41) of the earth electrode (40) are 1.1 [mm] or less in diameter.

12. An ignition apparatus having a spark plug comprising:

a mounting bracket (10) capable of being mounted to an internal combustion engine;

a center electrode (30) insulatedly-supported by the mounting bracket, one end (31) of which being a pillar-like form and exposedly extending from one end (11) of the mounting bracket; and

an earth electrode (40) having one end coupled with the

one end of the mounting bracket and the other end on which one surface (43) is formed to face to the one end of the center electrode, the one surface having a pillar-like protrusion (41) being secured thereon and extending toward the center electrode so as to face the one end of the center electrode, a spacing formed between the one end of the center electrode and the protrusion of the earth electrode serving as a discharge gap (50), both of the one end of the center electrode and the protrusion of the earth electrode being a sectional area of 4.2 [mm<sup>2</sup>] or less at all positions each perpendicularly crossing an axial direction of each of the one end and the protrusion, and an amount of ignition energy required by the spark plug being less than 17 [mJ].

13. An ignition apparatus having a spark plug comprising:

a mounting bracket (10) capable of being mounted to an internal combustion engine;

a center electrode (30) insulatedly-supported by the mounting bracket, one end (31) of which being a pillar-like form and exposedly extending from one end (11) of the mounting bracket; and

an earth electrode (40) having one end coupled with the one end of the mounting bracket and the other end on which one surface (43) is formed to face to the one end of the center electrode, the one surface having a pillar-like protrusion (41) being secured thereon and extending toward the center electrode so as to face the one end of the center electrode, a spacing formed between the one end of the center electrode and the protrusion of the earth electrode serving as a discharge gap (50), both of the one end of the center electrode and the protrusion of the earth electrode being a sectional area of 4.2 [mm<sup>2</sup>] or less at all positions each perpendicularly crossing an axial direction of each of the one end and the protrusion, and a density of ignition energy required by the spark plug being less than 32 [W].

14. A spark plug comprising:

a mounting bracket (10) capable of being mounted to an internal combustion engine;

a center electrode (30) insulatedly-supported by the mounting bracket, one end (31) of which being a pillar-like form and exposedly extending from one end (11) of the mounting bracket; and

an earth electrode (40) having one end coupled with the one end of the mounting bracket and the other end on which one surface (43) is formed to face to the one end of the center electrode, the one surface having a pillar-like protrusion (41) being secured thereon and extending toward the center electrode so as to face the one end of the center electrode, a spacing formed between the one end of the center electrode and the protrusion of the earth electrode serving as a discharge gap (50), both of the one end of the center electrode and the protrusion of the earth electrode being a sectional area of 4.2 [mm<sup>2</sup>] or less at all positions each perpendicularly crossing an axial direction of each of the one end and the protrusion, and the discharge gap being 0.7 [mm] or less in length.

15. The spark plug of claim 14, wherein the mounting bracket (11) has an outer circumferential surface therearound on which a threaded part (12) to be thread-coupled with the internal combustion engine is formed, a thread diameter of the threaded part being M12 or less.

16. A spark plug comprising:

a mounting bracket (10) capable of being mounted to an internal combustion engine;

a center electrode (30) insulatedly-supported by the mounting bracket, one end (31) of which being a pillar-like form and exposedly extending from one end (11) of the mounting bracket; and

an earth electrode (40) having one end coupled with the

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one end of the mounting bracket and the other end on which one surface (43) is formed to face to the one end of the center electrode, the one surface having a pillar-like protrusion (41) being secured thereon and extending toward the center electrode so as to face the one end of the center electrode, a spacing formed between the one end of the center electrode and the protrusion of the earth electrode serving as a discharge gap (50), both of the one end of the center electrode and the protrusion of the earth electrode being a sectional area of 4.2 [mm<sup>2</sup>] or less at all positions each perpendicularly crossing an axial direction of each of the one end and the protrusion, and a protruding length (L) of the protrusion being 0.3 [mm] or more.

17. The spark plug of claim 16, wherein the protruding length (L) is 1.5 [mm] or less.

18. The spark plug of claim 14, wherein both of the one end (31) of the center electrode (30) and the protrusion (41) of the earth electrode (40) are a sectional area of 1 [mm<sup>2</sup>] or less at all positions each perpendicularly crossing an axial direction of each of the one end and the protrusion.

19. An ignition apparatus comprising:  
the spark plug (S1) of claim 14; and  
an ignition power supply (60) for applying voltage to the center electrode (30) and the earth electrode (41).

20. An ignition apparatus comprising:  
the ignition plug (S1) of claim 14; and  
an ignition power supply (60) having an ignition coil for applying voltage to the center electrode (30) and the earth electrode (41), the ignition coil being 22 [mm] or less in coil diameter.

21. An ignition apparatus comprising:

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a spark plug having  
a mounting bracket (10) capable of being mounted to an  
internal combustion engine,

5 a center electrode (30) insulatedly-supported by the  
mounting bracket, one end (31) of which being a pillar-like form  
and exposedly extending from one end (11) of the mounting  
bracket, and

10 an earth electrode (40) having one end coupled with the  
one end of the mounting bracket and the other end on which one  
surface (43) is formed to face to the one end of the center  
electrode, the one surface having a pillar-like protrusion (41)  
being secured thereon and extending toward the center electrode  
so as to face the one end of the center electrode, a spacing  
15 formed between the one end of the center electrode and the  
protrusion of the earth electrode serving as a discharge gap  
(50), both of the one end of the center electrode and the  
protrusion of the earth electrode being a sectional area of 4.2  
[mm<sup>2</sup>] or less at all positions each perpendicularly crossing  
20 an axial direction of each of the one end and the protrusion,  
and the protrusion being made of one selected from a group  
consisting of a platinum-based alloy and an iridium-based  
alloy; and

25 an ignition power supply (60) for applying voltage to the  
center electrode (30) and the earth electrode (41), a positive  
voltage being applied to the center electrode by the ignition  
power supply when a discharge starts.

30 22. The ignition apparatus of claim 12, wherein both of  
the one end (31) of the center electrode (30) and the protrusion  
(41) of the earth electrode (40) are a sectional area of 1 [mm<sup>2</sup>]  
or less at all positions each perpendicularly crossing an axial  
direction of each of the one end and the protrusion.

35 23. An ignition apparatus having a spark plug  
comprising:

a mounting bracket (10) capable of being mounted to an



internal combustion engine;

a center electrode (30) insulatedly-supported by the mounting bracket, one end (31) of which being a cylindrical form and exposedly extending from one end (11) of the mounting  
5 bracket; and

an earth electrode (40) having one end coupled with the one end of the mounting bracket and the other end on which one surface (43) is formed to face to the one end of the center electrode, the one surface having a cylindrical protrusion (41) being secured thereon and extending toward the center electrode  
10 so as to face the one end of the center electrode,

wherein an ignition energy  $E$  [mJ] is applied to the spark plug so that an ignition occurs between the center and earth electrodes, a diameter  $D$  of the protrusion is 0.4 [mm] or more,  
15 but 2.3 [mm] or less, and relationships of

$$0.3[\text{mm}] \leq L \leq 0.016E^2 - 0.56E + 5.2[\text{mm}]$$

$$\text{in which } 8.5[\text{mJ}] \leq E \leq 17[\text{mJ}]$$

are realized between a length  $L$  of the protrusion and the ignition energy  $E$  [mJ].  
20

24. The ignition apparatus of claim 23, wherein both of the one end of the center electrode and the protrusion of earth electrode are 4.2 [mm<sup>2</sup>] or less in sectional area and a density of the ignition energy is 32 [W] or less.

25. The ignition apparatus of claim 23, wherein both of a diameter  $D1$  of the one end of the center electrode and a diameter  $D2$  of the protrusion of earth electrode are 2.3 [mm] or less and a relationship of

$$1.5D2^2 + 0.1D2 + 8[\text{mJ}] \leq E < 0.34D1^2 + 0.2D1 + 16.4[\text{mJ}]$$

30 between the ignition energy  $E$  [mJ] and the diameters  $D1$  and  $D2$  is realized.

26. The ignition apparatus of claim 23, wherein both of a diameter  $D1$  of the one end of the center electrode and a diameter  $D2$  of the protrusion of the earth electrode are 2.3  
35

[mm] or less and a relationship of

$$3D2^2+0.2D2+16[W] \leq Q < 0.68D1^2+0.4D1+32.8[W]$$

between the density of the ignition energy Q [W] and the diameters D1 and D2 is realized.

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27. The ignition apparatus of claim 24, wherein both of a diameter D1 of the one end of the center electrode and a diameter D2 of the protrusion of the earth electrode are 2.3 [mm] or less and a discharge (50) formed between the one end and the protrusion is 0.7 [mm] or less in distance.

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28. The ignition of claim 25, wherein the mounting bracket (11) has an outer circumferential surface therearound on which a threaded part (12) to be thread-coupled with the internal combustion engine is formed, a thread diameter of the threaded part being M12 or less.

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29. The ignition apparatus of claim 28, wherein the protruding length L of the protrusion on the earth electrode is 1.5 [mm] or less.

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30. The ignition apparatus of claim 29, wherein the protruding length L is 0.8 [mm] or less.

25

31. The ignition apparatus of claim 27, wherein both of the one end (31) of the center electrode (30) and the protrusion (41) of the earth electrode (40) are 1 [mm<sup>2</sup>] or less in a sectional area.

30

32. An ignition apparatus comprising:  
the ignition plug (S1) of claim 27; and  
an ignition power supply (60) having an ignition coil for applying voltage to the center electrode (30) and the earth electrode (41), the ignition coil being 22 [mm] or less in coil diameter.

35

33. An ignition apparatus comprising:  
a spark plug having  
a mounting bracket (10) capable of being mounted to an  
internal combustion engine,

5 a center electrode (30) insulatedly-supported by the  
mounting bracket, one end (31) of which being a cylindrical form  
and exposedly extending from one end (11) of the mounting  
bracket, and

10 an earth electrode (40) having one end coupled with the  
one end of the mounting bracket and the other end on which one  
surface (43) is formed to face to the one end of the center  
electrode, the one surface having a cylindrical protrusion (41)  
being secured thereon and extending toward the center electrode  
so as to face the one end of the center electrode; and

15 an ignition power supply (60) for applying voltage to the  
center electrode (30) and the earth electrode (41), positive  
electric charges being applied to the center electrode by the  
ignition power supply when starting ignition,

20 wherein both of the one end of the center electrode and  
the protrusion of the earth electrode is 2.3 [mm] in diameter.

34. The ignition apparatus of claim 23, wherein both of  
the one end (31) of the center electrode (30) and the protrusion  
(41) of the earth electrode (40) are 1 [mm<sup>2</sup>] or less in a sectional  
25 area.

35. The ignition apparatus of claim 23, wherein the  
protrusion (41) of the earth electrode (40) is made of an alloy  
of which main composition is Pt and to which at least one  
30 component selected from the group consisting of Ir, Ni, Rh, W,  
Pd, Ru and Os is added.

36. The ignition apparatus of claim 23, wherein the  
protrusion (41) of the earth electrode (40) is made of an alloy  
35 of which main composition is Pt and to which at least one  
component selected from the group consisting of 0 to 50 wt% of

Ir, 0 to 40 wt% of Ni, 0 to 50 wt% of Rh, 0 to 30 wt% of W, 0 to 40 wt% of Pd, 0 to 30 wt% of Ru, and 0 to 20 wt% of Os is added.

5 37. The ignition apparatus of claim 23, wherein the protrusion (41) of the earth electrode (40) is made of an alloy of which main composition is Ir and to which at least one component selected from the group consisting of Rh, Pt, Ni, W, Pd, Ru and Os is added.

10 38. The ignition apparatus of claim 23, wherein the protrusion (41) of the earth electrode (40) is made of an alloy of which main composition is Ir and to which at least one component selected from the group consisting of 0 to 50 wt% of Rh, 0 to 50 wt% of Pt, 0 to 40 wt% of Ni, 0 to 30 wt% of W, 0 to 40 wt% of Pd, 0 to 30 wt% of Ru, and 0 to 20 wt% of Os is added.